Gasdynamic Mirror Fusion Propulsion Experiment

Project Number 97-06

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Purpose

The purpose of this project is to construct a small device that would provide preliminary feasibility tests of a gasdynamic mirror (GDM) fusion propulsion system. This particular fusion concept seems to be particularly well suited to propulsion applications since a full-size device is projected to have specific impulses in excess of 100,000 sec with thrust levels approaching 1,000 pounds and reasonable system weights. The full-scale engine would operate at much higher plasma densities and with much larger L/D ratios than previous mirror machines. Several advantages accrue from such a design. First, the high L/D ratio minimizes to a large extent certain magnetic curvature effects which lead to plasma instabilities. This causes a loss of plasma confinement. In particular, this feature should make it possible to suppress the "flute" instability which is known to cause magnetohydrodynamic (MHD) instabilities in classical mirror fusion designs. Second, the high plasma density will result in the plasma behaving much more like a conventional fluid with a mean free path shorter than the length of the device. A short mean free path implies that a majority of the hydrogen ions will undergo fusion reactions prior to being reflected at the magnetic mirror reflectors at the end of the device. This characteristic helps reduce problems associated with "loss cone" microinstabilities. This results from a depletion of the particle velocity distribution function in that these instabilities will not cause the longitudinal confinement time to be reduced below a certain level.

Background

There have been numerous theoretical and experimental studies in the past related to the development of a practical fusion reactor. A large mirror fusion machine was built at the Lawrence Livermore Laboratories, although it was never tested due to funding constraints. The design of this machine was similar in some respects to the device proposed here, although its magnetic geometry was somewhat more complex, and it was to operate at much lower plasma densities. Several other smaller mirror machines in the past have also been built and operated.

The largest fusion device currently operating is the TFTR at Princeton. This is a tokamak (torodial) device whose geometry is considerably different than the one proposed here. It has recently operated with reacting plasmas and has achieved near breakeven conditions; however, it is currently due to be shut down. The gasdynamic mirror fusion device being proposed here was described recently in the *Journal of Propulsion and Power*.[1]

Approach

The experimental device for this study will contain a high density hydrogen or argon plasma about 15 cm in diameter with an ion temperature of approximately 5 eV. The device is designed to have a variable length which is accomplished by having either one or two segments in operation yielding lengths of either 2.5 m or 4.5 m. The plasma density will be approximately 1×10^{14} ion/cm^3. Because only relatively low-temperature hydrogen plasmas will be used in this device, there will be no need for the radiation shielding that would be required in machines which have high-temperature reacting plasmas.

The experimental studies for this project will investigate the most important physics issues related to the GDM concept such as plasma confinement, equilibrium, and stability. This information will allow the dynamic behavior of the plasma to be sufficiently understood such that a more extensive computational and experimental program may be initiated to allow a full assessment of the device's performance. In particular, the confinement properties of the gasdynamic mirror will be studied in detail to determine the effects of the induced electrostatic potential in the device. This is caused by the initial rapid escape of electrons from the system. The study will also determine the device's stability against both the MHD flute instability and the loss cone microinstability.

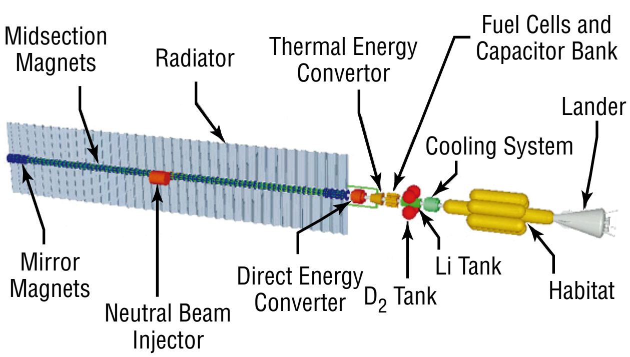

FIGURE 17.—Interplanetary vehicle using a gasdynamic mirror fusion propulsion system.

Accomplishments

- Detailed design of the device and an outline of the experiments to be performed has been completed;
- Most of the equipment has been purchased. About 50 percent has been received;
- Construction of the main plasma chamber support structure is essentially complete.

Planned Future Work

Complete construction of the GDM device. This includes:

- Mounting the magnets on the main plasma chamber and attaching the chamber to the support structure;
- Constructing the mirror magnet assemblies and attaching them to the support structure;
- Connecting the vacuum equipment to the device and installing electrical connections to the magnets;
- Installing the plasma injector system and diagnostic systems; and
- Performing the initial experiments to assess the device's stability against both the MHD flute instability and the loss cone microinstability.

Publications

- Improved Physics Model for the Gasdynamic Mirror Fusion Propulsion System
- Physics Basis for the Gasdynamic Mirror (GDM) Fusion Rocket
- Interplanetary Missions With the GDM Propulsion System

Funding Summary ($k) FY97

Obligated for equipment: 107k

Status of Investigation

Project approval—October 31, 1996
Estimated completion—December 31, 1998

Reference

[1]Kammash, T.; and Lee, M.: "Gasdynamic Fusion Propulsion System for Space Exploration," *Journal of Propulsion and Power*, Vol. 11, No. 3, May–June 1995.